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Chief Engineer at Ostashkov, calling for the design of a missile having a range of 3,000 km. and carrying a warhead of 3,000 kg. GOETTRUP in turn notified the various German section Chiefs, transmitted the Soviet requirements, and informed them that the project was to be completed by 1 Oct 49. The German engineers were apparently given complete freedom in respect to the type and form of missile to be designed, with the Soviet control and direction being solely confined to the issuance of the initial requirements as specified above.

2. In order to understand the course pursued by the German engineers in their efforts to comply with the Soviet demands, it is necessary to briefly describe their activity in the preceeding years.
3. During the years 1947 until the beginning of 1949, the primary task at Ostashkov, a task which engaged nearly every section of the Institute. was the design of the R-10 missile.

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A few especially qualified engineers representing several sections, intermittently side-tracked their attention to the study of missiles having a range far above that of the R-10. There appears to be some confusion as to the purpose of this work. In a sense, the inspiration for these studies came from Soviet sources. For example, in visits made to the Institute dating back to 1948, Korolov, a Soviet colonel, repeatedly voiced interest in the design of a missile having a range of 10,000 km. It may well be that, in an attempt to satisfy specific requirements, individual scientists engaged in these private studies during breathing spells of the R-10 project and immediately after its completion. Whether or not these studies laid the ground work for the R-14 Project or were associated with the Soviet research and development program is difficult to ascertain. Certainly, the ambiguity surrounding this point is not lessened by the Soviet research system with its apparently numerous and subtle distinctions, such as "Vorprojekt", "Avantprojekt", "Erstes Skizzen Projekt", etc.

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the exact Soviet description of the R-14 was "Skizzenprojekt".

4. the direct relation between the R-14 project and these studies is unlikely, since apparently the required range of 3,000 km. with a 3,000 kg. load exceeded by far any of the proposals submitted by the Germans. Furthermore, no German was able to identify the requirements for the R-14 as reflecting his own proposals. In addition, it would seem that the Soviets would have made reference to a particular study were the R-14 based on it. It will, however,

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be remembered that the requirements for the R-14, while more specific than the requests of Colonel Korolov, were nevertheless very general, specifying only range and warhead dimensions.

5. The various studies of the period 1948 to 1950 assume importance in relation with the R-14 project only in the fact that these studies incorporated some of the information gathered during that time and, specifically, that the origin of the radically changed motor which was a part of the R-14, lies in this period. One of the studies made during this period was one relating rocket thrust and increased combustion pressures. The thermodynamic department did much on this

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6. Upon receipt of Soviet requirements, the German engineers prepared various proposals for a period of approximately five weeks aimed at satisfying the required range and warhead load. Essentially, four major proposals were submitted from which two were selected for detailed and concentrated effort. The four proposals were as follows:

- a. The construction of a conic shaped missile using several A-4 motors. The number of motors proposed was usually between four and six. To lessen the weight of the missile, it was contemplated that the expended motors be dropped from the missile from various heights.
- b. Use of multi-stage rockets which had been studied as the R-12 project during the years 1948 and 1949. In this, a number of rockets were to surround a missile carrying the warhead. The first stage was to be provided by the surrounding missiles which, at a certain height, would release the warhead-carrying missile on its second stage of powered flight.
- c. Design of a pilotless supersonic aircraft to be launched from the ground by means of an A-4 type rocket. Upon reaching a speed of 500 to 600 m/seconds the plane would begin to produce its own propulsion until reaching an altitude of approximately 25 km. The loss in weight and the increase in lift would cause the plane to climb to approximately 30 to 40 km. From this altitude the direct descent to the target would ensue.

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- d. Construction of a missile using an entirely new motor.

7. As stated, two proposals were selected by the Soviet administration for detailed study—the supersonic aircraft which became known as project R-15, and the missile with a new motor, Project R-14.

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The order to pursue the two projects came from the Soviet Chief Engineer at Ostashkov, but this decision was made at a higher level, presumably the responsible Ministry in Moscow. This decision having been made, the German engineers in Ostashkov were divided into two groups, the larger of which was assigned to the R-14 project and the other headed by Dr. ALBRING to the R-15 project. Until 1 Oct 49, approximately 60 per cent of the German specialists were engaged in these studies. Excluded were only the workshop section and the radio and chemical section. Of the 60 per cent that were assigned to the two projects, approximately 80 per cent worked on the R-14 project. The personnel were essentially the same as that which worked on the R-10 project.

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BASIC DATA

8. The basic characteristics of the R-14 are as follows:

a. Weight Analysis of the Empty Missile

Nose	60 kg.	
Warhead	3400 kg.	{(3,000 kg. explosives)}
Central Section	1390 kg.	
Stabilizing Ring	260 kg.	
Motor Mount	400 kg.	
Turbines, Pumps, Pipelines, and Instruments	550 kg.	
Controls	100 kg.	
Weight Empty	6160 kg.	

b. Fuels

A - Liquid oxygen $\gamma = 1.13$
 B - Alcohol-water mixture $\gamma = 0.89$ (approximately 70 per cent alcohol and 30 per cent water)

A - fuel	36877 kg.	32640 dcm ³
B - fuel	26963 kg.	30280 dcm ³
A + B	63840 kg.	62920 dcm ³

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c. Fuel Consumption per Second

A - fuel $251 = 251 \text{ kg.} + 2.5\% = 253.5 \text{ kg.} = 58$
per cent
B - fuel $171 + 12\% = 183 \text{ kg.} + 1\% = 184 \text{ kg.} =$
42 per cent

*Additional consumption for gasing of A-container
**Additional consumption for gasing of B-container
***Estimated additional consumption for the cooling
of gas for the starting of the turbines

d. Motor Thrust

On the ground, thrust approximately 101,000 kg.
At great altitude, thrust approximately 108,000 kg.

The specific thrust at extreme altitude would be
approximately

$$I_{ps} = \text{approximately } \frac{108,000}{434} = 249 \text{ kg/kg-sec}$$

e. Residual Fuel at Propellant Cut-Off

A - in gaseous state in the A container	approx. 362 kg.	
- in the starting unit (propulsion unit)	" 120 kg.	482
B - in gaseous state in the B container	approx. 145 kg.	
- in the starting unit (propulsion unit)	" 150 kg.	
- in the B container	" 163 kg.	458
Total A & B		940

Of this approx. 270 kg.
would remain in the
propulsion unit

f. Combustion Period (Maximum)

$$t = \text{approximately } \frac{63840 - 940}{434} = 145 \text{ sec.}$$

As a result of the thrust reduction during the final
part of the flight in order to keep acceleration less
than 10 g's, the combustion period was to be increased
by an additional 11 seconds. Therefore, the actual
combustion period would become:

$$t = \text{approximately } 145 + 11 = 156 \text{ seconds.}$$

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g. Launching Weight

The launching weight obtained from the weight empty and the weight of the fuels would be:

$$W_1 = 6160 + 63840 = 70000 \text{ kg.}$$

h. Weight at Propellant Cut-Off

The weight at cut-off obtained from the weight empty and the weight of the residual fuels becomes:

$$W_{co} = 6160 + 940 = 7100 \text{ kg.}$$

i. Maximum Cut-Off Speed

$$v_{co} = \text{approximately } 4500 \text{ m/sec.}$$

j. Maximum Target Range

$$s = \text{approximately } 3,100 \text{ km.}$$

DESCRIPTIONGeneral

9. The first sketch [see page 23] is a layout of the R-14 missiles as designed by the Germans. As can be seen from the layout, the missile was a long conic-shaped body powered by a single rocket motor and controlled through the angular deflection of this motor. The missile design consisted of a nose section, war-head, central section, and stabilizing ring [which will be discussed individually in the following sections of this report]. The contours shown here are those submitted to the Soviets in October 1950. The dimensions [redacted] have been derived through calculation. The overall measurements are accurate to within 50 centimeters and the diameters and central section taper are almost exact. The least accurate dimensions are those of the nose length and taper. The rocket motor location is in error by only a few centimeters. 25X1
10. As stated previously, the R-14, for which there was never any other designation to my knowledge, was selected for design over several other proposals. [redacted] the reasons for selection were many and included the following: 25X1

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- a. Mechanical advantages through simplicity. The fin and rudder system could be eliminated by maintaining stability through proper location of center of gravity and center of pressure.
 - b. Aerodynamic advantages of the cone shape in supersonic flight. Although this shape was not advantageous for the initial phase of the flight, the air resistance encountered would not be intolerable. The relatively low speeds in the denser atmosphere would keep these resistances small. The advantages of simplicity and weight-saving over resistance justified the selection of this shape.
 - c. Further exploitation of the German engineers. A missile design incorporating radically new ideas could open many more fruitful facets for the overall Soviet research program than a mere modification of a traditional missile design.
11. To fully understand the design presented here, a few words should be inserted regarding the ballistics of the missile. The ballistic path of the R-14 was to be essentially the same as that of the A-4 missile except that the range was to be increased to 3000 km. The missile was to be launched vertically, gradually controlled to a flight path of approximately 35°, and continue under powered flight for approximately 155 seconds. However, at a predetermined point after propellant cut-off, the nose and body of the missile were to separate from the warhead and continue along an elliptical flight path. The warhead would continue to the target as a free falling body.
12. In the course of the design of the R-14 many problems arose which were by-passed or ignored because of the time allotted to the Germans and because there was effectively no experimentation work carried on in conjunction with the project. When problems such as control at critical speeds, ballistic of free falling cylinders, and weldability of certain parts were encountered, they were dismissed as being technically feasible but requiring further development and the project continued. There were never any estimates made regarding the number of manhours required to construct such a missile. Since, by U.S. standards, the project could still be classed as a preliminary design study.

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Nose Section

13. A cross sectional view of the proposed nose section of the R-14 missile is shown on the second sketch see page 25 7.
14. The nose of this missile had the sole purpose of reducing air resistance of the missile during the ascending portion of the flight. Since no functional requirements had to be met other than to reduce air resistance, this part was designed for simple and inexpensive construction. In order to keep dimensions to a minimum, the principle of internal pressure within a circular body was employed. An opening was provided in the apex of the cone so that ram pressure could be utilized to increase the internal pressure. This would counteract external pressures to a certain degree and would provide the skin with tensile stability.
15. The material decided on for the skin was plywood. Thus, a sufficient thickness could be used to provide the relatively long cone with load stability and prevent buckling. The material would be partially burnt away during high speed flight, but it was felt that the thickness was sufficient to permit enough material to remain at extreme altitudes where loads were small.
16. Formers, made of laminated wood, were provided for the additional support needed when an uneven circumferential pressure distribution occurred during flight at angles of incidence.
17. In order to prevent internal air leakage or suction at the rear of the nose, a seal was provided. The seal and the method of attachment of the nose section to warhead can be seen in detail in view C on page 27. 7 The air inlet consisted of a steel insert.

Warhead

18. Another sketch see page 27 7 shows a cross sectional view of the proposed warhead for the R-14. Enlarged views are presented to show the details of the various joints.

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19. The design of the warhead was a radically new design developed solely by the Germans. As briefly mentioned previously, the warhead was to be separated from the nose and central section of the missile shortly after propellant cut-off. The separation was to be accomplished by the explosive charges, points (7) and (12). The manner or technique of setting off the charge was not investigated or planned. Since the resistance in space would be negligible, the various components of the missile would continue in flight until reaching a denser atmosphere where the warhead would free itself entirely. It was realized that as the warhead approached the atmosphere, violent oscillation would occur, but through proper location of center of gravity and pressure, the oscillation would increase in frequency and decrease in amplitude until a stabilized flight condition was reached. As shown in the drawing, the location of the center of pressure with respect to center of gravity was accomplished by extending the cylinder walls at the rear of the explosive. As the warhead entered the denser atmosphere belt, a violent deceleration would also occur because of the large resistance resulting from the flat frontal area.
20. The drawing shows that the entire warhead casing was to be made of wood. The selection of wood with its low specific weight permitted large wall dimensions.
21. As in the R-10 project, the principle of partially destroying the casing through burning was to be utilized. The thickness of the walls was of such magnitude that a sufficient quantity of wood would remain at the end of the flight path. Since the descending speed of the cylinder would be reduced in the denser atmosphere, the amount of wood destroyed would also be reduced.
22. In addition, the selection of wood was advantageous because of its low heat conductivity. It was felt that the quantity of heat transmitted to the explosive would remain within tolerable limits as a result of this property, plus other facts. Since the speed was relatively reduced, the heat generated would be reduced. Also, because of the flat frontal area of the cylinder in descent, a stagnation area would build up and, thus, reduce the heat factor considerably.

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23. Again, a great deal of this behavior was surmised since no absolute technical data was available regarding heat generation in flight and no significant experimental work was carried out on the destruction of wood in flight.
24. From the structural standpoint, calculations showed that the wood body could withstand the subjected loads. Should the estimates made on the amount of wood remaining in the walls be correct, the material plus the rigidity of the explosive itself would be sufficient to absorb the loads imposed in oscillation. Longitudinal forces on the front panel resulting from rapid deceleration of the explosive would be partially counteracted by the air pressure on the front panel. Calculations proved that the rear panel with properly cemented joints could support the explosive under the contemplated 10 g's acceleration during powered flight.

25. [REDACTED] Since there were no explosive experts available, this problem was ignored. The casing was structurally designed to rely partially on the support of the explosive.

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The method of attachments of the warhead to the nose and central section are sufficiently clear in the detailed views A and C on page 27.

Central Section

Sketch on page 29 shows the central section and stabilizer ring of the R-14 missile. Included on page 29 and the sketch on page 30 are several design details of interest.

26. The design of the central section called for a single-shell self-containing structure similar in many respects to that of the central section of the R-10 missile. The concepts underlying the design are principally those used in the R-10. That is, the transmission of loads, the use of internal pressures for support, transmission of heat, etc. are similar and will not be expounded upon here.

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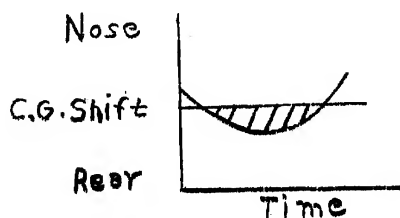
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27. Briefly, the structure consisted of a thin wall skin reinforced by a system of formers. The conical shell was sealed off at its extremities by panels and was divided into two compartments by a curved partition. The warhead of the missile was attached directly to the shell [as shown in view A on page 27]. The stabilizer ring was attached to the rear of the shell [in the manner shown in view D on page 30].

28. One of the major points of interest and a matter which differs basically from the design of the R-10 is the location of the liquid oxygen and the alcohol. This design called for the liquid oxygen to be located in the forward compartment and the alcohol in the rear. One of the reasons for this shift was a matter of stability. By placing the more dense or heavier liquid in the forward compartment, the center of gravity of the missile could be moved further forward. Calculations showed that even with this change, the missile would approach instability during a portion of the powered flight. That is, as the oxygen was consumed, the center of gravity moved to the rear and then forward again. This can be represented by the following curve:



29. To compensate for this approach to instability, the stabilizer ring could have been lengthened and, thus, shift the center of pressure further to the rear. To lengthen the stabilizer ring would have increased the weight and also the air resistance as a result of a correspondingly larger frontal area. It was found that the missile could be stabilized to a certain extent by use of the motor and turbine nozzle controls. It then became a matter of compromise between the extent of stability through the structural design and the exhaust. An accurate plot of the above curve was possible with some portion of the curve shaded as above indicating the duration and extent of control required by the propulsion system.

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30. Because of the high fuel injection pressures of approximately 70 atmospheres required for the new motor, extremely high speed pumps were required. This led to a danger of cavitation at the pump inlet unless sufficient pressure was provided at this point. The danger of cavitation was especially pronounced for liquid oxygen, which at a temperature of -183°C is near the boiling point. To provide the required inlet pressures, the pressure within the containers of both the liquid oxygen and the alcohol was raised to approximately 2.8 atmospheres. Placing the oxygen in the forward or upper compartment of the shell produced an additional head of approximately 2.2 atmospheres so that the critical liquid oxygen had a total pressure head of approximately 5 atmospheres at the pump inlet. The non-critical alcohol had a total head of approximately 3.5 atmospheres. Thus, the combination of increasing internal tank pressure and shifting of oxygen to the forward compartment alleviated one danger. The dangers or problems encountered with the shell as a result of increasing internal pressure will be discussed briefly.
31. Another point of interest and a departure from the R-10 design was the selection of material for the skin of the central section. While working on a preliminary project after the completion of the R-10 design, I was introduced, by the Soviets, to an entirely new high quality steel. This steel had excellent welding characteristics and a tensile strength in the welded condition of approximately 100 kg/mm^2 , whereas the Germans had never known of steel having a strength in excess of 70 kg/mm^2 . The Soviet designation was not known to me. The Germans managed to obtain a small piece of this material and tested it for rupture and impact at low temperatures (-183°C). The material became brittle and the characteristics at low temperatures were not good, but, nevertheless, were far better than those of other steels, and the tests indicated it would have sufficient strength for the missile.
32. This high quality steel appeared to be an excellent choice in view of the great internal pressure and tensile loads to which the skin would be subjected. The use of this material was strongly pressed by the construction personnel who appreciated its welding characteristics over that of light metal. In addition, the possibilities interested other members

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of the group and so the design continued based on this material. As the design progressed, it became evident that a light metal would possibly have more advantages, but the final design presented called for the steel shell. In December 1949, after the design had been submitted, the Soviets asked for a design of the central section using light metal of a two millimeter skin thickness. Actually, the design was the same as the other with merely a substitution of material. It resulted in a slightly heavier body [redacted] a design originated and based on light metal would eventually produce a lighter body.

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33. [redacted] in truth, neither the light metal, nor the new steel design were fully exploited so that it was not clear which had the advantage over the other. As an example, the skin thickness of the new steel could possibly have been reduced to six tenths of a millimeter. At the time of the actual design, there were many qualities of the new steel such as bending and forming characteristics that were not known and so were dismissed for the time being.

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34. [redacted] Based on the difficulty in obtaining a small piece for test, [redacted] it was merely an experimental material and not abundant. [redacted] the Soviets did not object to the use of the material in the design of the R-14. The fact that the material might be in a stage of development would not exclude its use in a design of an object which itself could only be years from production.

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35. A major problem in the design of a thin-walled missile is the transmission of motor forces to the body. The R-14 design called for the introduction of the motor thrust directly into the rear panel. The panel was designed as a conical shaped wall with the apex consisting of the female-portion of a ball and socket joint. [See view G on page 30.] The extremities of the conic panel were curved and joined the skin of the container shell [as shown in view D]. The conic panel was tapered with the maximum thickness being at the apex and the minimum thickness at the container wall. The motor made contact with the rear panel solely by means of the ball and socket so that all thrust or longitudinal force would be introduced at the apex of the panel. This would produce a load concentration at the apex and a

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decreasing load at points along the diameter of the conic panel. Acting on the panel in an opposite direction would be forces resulting from the internal pressure. At some point along the diameter of the conic panel the opposite forces would cancel each other so that the resulting force at the extremities of the panel would be one of tension. The tensile force would be distributed around the circumference with no local concentration and could be supported by the thin wall.

36. View G is a cross section of the ball and socket gimbal arrangement. It was originally planned to use a modified knife edge, but it was found necessary to have a close fitting ball and socket to prevent lateral travel and to distribute the load over a larger area. The plate had to assume large proportions in thickness to prevent bending and, thus, concentrations of loads. The intersection of the thrust cone forces within the plate would also prevent bending moments. Struts not shown were provided to prevent the separation of the gimbal under conditions of no power.
37. The apex of the rear panel was to serve also as a manhole cover for access to the container. See view F. The feed pipe (13) from the forward compartment to the power unit was similar to that used in the R-10 design. In this design the insulation served to keep heat from the flowing liquid oxygen. The outer casing was corrugated as before to provide strength and to permit expansion and contraction. A glass wool insulation was used between the casing and pipe. The expansion and contraction of the pipe (19) was to be compensated for through a metallic bellows union.
38. Not clearly shown in the details are the slotted flanges of the formers. These slots permitted the formers to be flexible during deformation of the skin. Again the design and concepts for the R-14 formers were similar to those of the R-10.

Stabilizer Ring

39. Since the flight stability of the R-14 was to be maintained through proper relation of center of pressure and gravity and through motor exhaust control, the conventional complicated fins were no longer necessary and the design need only to provide for a single ring whose sole purpose was to shift the center of pressure rearward.
40. Simplicity became a keynote. It was obvious that a normal sheet metal ring would require a network of spars and formers for support. The heat generation in high speed flight would cause the expansion of skin, spars, and formers at a different rate since the spars would have to be of a larger mass. This would all add to further complications to an already complicated system. It was decided then to use a corrugated light metal to serve the purpose of skin and supporters. Formers would be required only at great intervals and the expansion of the skin by boundary layer heat could take place between the riveted points of attachment to the formers. This permitted a simple but effective design and is shown in detail on page 30.

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41. Actually, the greatest forces on a stabilizing ring of this type would be when the missile approaches instability during mid-powered flight. At this time the speed would be relatively small and the heat generated comparatively small. When high speeds are reached and heat generation large, the missile would be quite stable and the stabilizer would be under relatively small loads.
42. Upon launching a missile of this type, it would be necessary to rest it on the corrugated stabilizing ring. To prevent local load concentrations, since the ring would have to support the entire weight of the loaded missile, an elastic launching ring would have to be provided. In this way it would be certain that the load would be distributed around the entire stabilizing ring.
43. As seen [in view D], the transfer of the forces from the ring to the central section, while the missile rests on the launching ring, would be slightly eccentric. To counteract the resulting twisting moment at this point the design provided for a relatively large former.

Propulsion Unit and Propellant System

Operation

(A schematic drawing [see page 32] shows the operating principle of the propulsion unit and propellant system contemplated for use in the R-14 design. It is presented primarily to show the flow of the propellants and is not to be taken as a true reproduction of component parts or location of component parts.)

44. Assuming the motor in operation, the flow would be as follows: The liquid oxygen would flow from the A-container into the feed pipe (10), through the flexible union (25) and the out-off valve (12). It would then enter the first stage of the pumps (14) and in turn the second stage. Each stage would produce a pressure rise of approximately 32 atmospheres. From the high pressure side of the pumps, the oxygen would flow into the high pressure line (15) and into the distributor ring for injection into the head of the combustion chamber. The pumps were to be driven by a high speed two-stage turbine which, in turn, would be driven by gas extracted from the combustion chamber. In principle the gas extraction was to be accomplished in a manner similar to the method discussed in the R-10 design. Basically, the extracted gas was to be cooled by means of alcohol heat extraction and also by alcohol injection.
45. The flow of the alcohol is slightly more complicated in that the alcohol was to be utilized as a coolant for the motor. A portion of the alcohol was to flow from the B-container through the feed line (26) by way of the flexible union (25) into the rear ring of the motor nozzle. It would then flow between the walls of the nozzle, collect in the forward nozzle ring, flow through the line (27) and into the first stage of a two-stage alcohol pump.

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46. The second portion of the alcohol would leave the B-container by way of the feed line (28), flow through the flexible union (25) and also flow into the first stage of the alcohol pump. The alcohol would receive a pressure rise of approximately 35 atmospheres and would then enter the second stage of the pump for an additional 35 atmosphere pressure rise. The alcohol would then flow through the high pressure line (36) into the forward distribution ring of the motor throat. In the ring the fuel was to be divided with the largest portion (approximately 80 per cent) flowing forward between the double wall of the combustion chamber and injected directly into the combustion chamber head by way of the injection cups (5) with a pressure drop to approximately 65 atmospheres. The remaining portion of the alcohol was to flow through small orifices and through a small channel between the walls of the throat. The pressure drop through the orifices would reduce the pressure to approximately 40 atmospheres and the pressure at the throat collection ring would be approximately 10 atmospheres. From the throat ring the alcohol was to flow through the line (35) back into the feed line (28) where it would produce an injector effect on the alcohol entering the first stage of the pump.
47. The alcohol pump turbine was to be driven by extracted motor gas obtained through the extraction pipe (32) in a manner similar to that previously described.
48. The venting, or more properly the gasing, of the A-container was to be accomplished by means of vaporizing a small quantity of liquid oxygen taken from the high pressure side of the pump. The oxygen was to be vaporized while passing through the vaporizer (19) and the pressure reduced to 2.8 atmospheres by means of the valve (20). The valve (20) also had the function of controlling the quantity of gas permitted to flow through line (21) to the upper part of the A-container.
49. Gasing of the B-container was to be accomplished by means of extracting exhaust gas from the turbine exhaust pipe (37). This gas was to be reduced and controlled also by a valve (40) prior to entering the upper portion of the B-container. The hot gases would be sufficiently cooled before reaching the upper portion of the container and would then mix with an inert gas so that there would be no danger of combustion in the container.
50. The exhaust from the turbines was to escape through the pipes (22) and (37) and the nozzles (24) and (39). These exhaust nozzles were to be adjustable in direction by means of the control motors (23) and (38). As a result the nozzle could serve two functions: one, to provide additional thrust (approximately 350 kg. per nozzle), and two, to control or prevent rotation of the missile about its longitudinal axis.
51. the total power absorbed by the two turbines was to be in the order of 6000 horsepower. 25X1
52. The A and B material mixture was to be regulated by means of the turbine speed. The unit (42) was to measure the fuel level by means of floats and an impulse sent to the command unit (43). On the basis of the impulses, the speed of the respective turbines would be increased or decreased as needed.

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53. Filling of the containers was to be accomplished through the one-way valves (11) and (29). The alcohol was to fill all lines and the pump and was prevented from entering the combustion chamber prior to starting by some means unknown to me.
54. Starting was to be accomplished by means of bringing the turbines up to speed with compressed air from an external source and brought in at valves (18) and (33). Shortly before the turbines reached operating speed, the valve (12) would be opened and the materials ignited by a method unfamiliar to me.

Design

55. A sketch of the design layout of the R-14 motor is shown see sketch on pages 34 and 35 as it was presented to the Soviets in October 1949. All dimensions are quite accurate according to source. As in the other drawings presented, many of the dimensions were recalled by performing a series of stress calculations based on that data source could remember. The dimensions that source could not produce with certainty are those pertaining to the throat, chamber, radii, and coolant slots. The throat diameter, however, is probably in error by only -.5 centimeters. The nozzle angle is exact with the wall thicknesses in error by plus or minus one millimeter.
56. The design presented was a rather complete theoretical presentation.
57. Upon attacking the design of the R-14 motor, the Germans found that the problems of cooling, expansion, and strength were extremely difficult ones; and that a solution would have to be based on different considerations from those familiar to them through the A-4 motor design. To review briefly, it will be recalled that the A-4 motor design was based on the principle of regenerative cooling with a single coolant stream and a relatively constant coolant pressure from the front to the rear of the motor. The result was a unit with extremely large dimensions.
58. As mentioned previously, the R-14 motor design made use of regenerative cooling with the alcohol as the coolant. However, the coolant was to be utilized in three systems with various selected pressures for each of the three stages. In order to eliminate many of the difficulties of cooling through thick walls and formers as experienced in the A-4 design, it was decided that the nozzle of the R-14 should utilize a low pressure cooling system with the pressure being that of the B-container. Even with this relatively low pressure, the difference between the coolant pressure and the exhaust pressure would be high and the forces exerted on the thin walls desired would be excessive. Therefore, longitudinal ribs (29) were provided between the two walls of the nozzle and spot welded to the walls. These ribs would serve as a connection between the two walls, and counteract the forces on the casing exerted externally and the forces on the inner

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wall exerted internally. These ribs permitted the dimensions of the inner wall to be reduced appreciably. They also served to eliminate the formers as in the case of the A-4 nozzle which were heavy and which restricted coolant flow.

59. The expansion of the inner wall of the rear portion of the nozzle and the casing would not cause too much difficulty. The inner wall would expand because of heat and the outer wall would follow because of the coolant pressure. Proper dimensioning of the outer casing would control the difference in rate of expansion and, thus, the rigid connection between the walls was permissible. The longitudinal strain in the ribbed portion that would arise as a result of the coolant flow between the walls was considered. Because the coolant pressure was small, it was found that the resultant strain was also small.
60. The portion of the nozzle between C-D would not be subjected to the loads expected in the rear portion, and so it was found that the ribs would not be needed for support. The increase of the inner wall thickness from 2.5 millimeters to 4 millimeters was provided in place of the ribs to satisfactorily support the coolant pressure and to carry the bending moments resulting from the motor deflection. The radial expansion between C and D was taken up by the coolant slot, and the longitudinal expansion was taken up by the bending of the thin wall of ring (22).
61. A radical solution was necessary to solve the problems arising in the critical throat area. In order to provide sufficient cooling, an extremely thin wall (20) of two millimeters was selected. To protect this wall, a thin coolant slot was provided to take advantage of the heat absorption qualities characteristic of the increased coolant speed and small coolant boundary layer. The selection of the slot dimensions was a compromise between an extremely thin slot with a high rate of heat absorption, and a thicker slot with a large quantity of heat absorption.
62. To satisfy the structural demands on the throat section, struts as those shown in view E-F were provided running the full length of the throat and at intervals determined by the loads. The loads resulting through expansion of the inner wall in the radial and longitudinal direction were permitted to exceed the elastic limit of the material and thus take advantage of the plastic effect. The longitudinal forces of the nozzle, the bending moments, and the forces arising out of the plastic effect were to be absorbed by the thick throat casing (21).
63. Film cooling was provided as an additional means of cooling the throat. A small amount of coolant was to be injected through the orifices (16) and permitted to flow along the throat wall where it would be vaporized. The size of the orifices was based on the coolant pressure and the internal pressure at the location of the respective orifices.
64. It was possible to maintain a relatively thin inner wall for the combustion chamber, since a small pressure differential would exist between the chamber pressure and coolant pressure, and since the spherical shape of the chamber was ideal for

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carrying forces. The resulting thin inner wall and a thin coolant slot, creating a pressure drop of approximately five atmospheres, would provide sufficient cooling. Should local hot spots occur, the inner wall would expand and decrease the coolant dimensions at that spot. The increase in coolant velocity would then provide an increase in the rate of cooling. The union of the inner wall to the injector cups would not be appreciably strained; since the cups would serve as a prop, the pressure differential would be small, and the temperature would be relatively low.

65. The outer wall, being spherical in shape, would also be ideal for absorbing the various forces introduced. In the area of the injector cups, where the surface would be interrupted by the cup openings, the wall thickness was increased to 10 millimeters. The thick wall was to be milled to provide a suitable union with the cup wall.
66. The ideal method of compensating for the difference in expansion of the inner and outer wall would have been to use a thin outer wall of high grade steel that would expand at a corresponding rate to the inner wall.
67. Since this condition could not be met, it was planned that the difference in longitudinal expansion would be taken up by the ring (14) while the radial expansion difference would be compensated for by predesigning the radii in the cold condition in such a way that the radii in the hot condition would be as desired. To prevent the coolant slot from completely closing or becoming too narrow at any time, wires with a circular cross section were to be placed longitudinally and welded to the inner wall.

68. [redacted] additional cooling was to be obtained in the combustion chamber by providing a series of orifices for film cooling.

69. [redacted] the liquid oxygen was to be injected through a copper plate with a series of orifices.

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A series of injection tests were performed at the Institute,

70. The thrust cone was to be attached tangentially to the outer wall of the combustion chamber and increased in thickness at the apex. Because of the thickness of the cone, walls and cups, the entire front portion of the motor would be extremely rigid. It was believed that this feature would be desirable with respect to vibration since the mass would be great and the frequency high. The elastic frontal portion of the A-4 motor with its low frequency was considered to be a weak point and it was hoped that the change would prove to be sound.

71. [redacted] the auxiliary equipment. [redacted] was placed as close to the gimbal as possible in order to keep the moments of inertia small. This applied to the pumps and turbines as well as the propellant lines. In addition, the lines had to

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entirely of paper, reflected the little time that was at the disposal of the engineers. Most of the drawings were over-all views with partial details on the same sheet similar to those presented in this report. No individual detail drawings suitable for use in construction were submitted and it seemed hardly probable that construction would ever be attempted from the sketches made available without a great deal of additional work.

80. After the information had been compiled, a commission appeared at the Island consisting of approximately ten Soviet scientists and engineers who [] represented various institutes in the area of Moscow. They had apparently been familiar with the R-14 and R-15 projects prior to their arrival. [] the aim of the commission was to study the projects. They had no contact with the Germans except when certain Germans were called in for consultation on points that were not clear to the commission. Two members of this commission were Cols. Pobedonostsev and Korolov. 25X1 25X1
81. The results of the commission's study were never known to me or my colleagues with the exception of two post projects that were immediately ordered. One project involved the design of a warhead that utilized its kinetic energy, and the second project was the design of a central section utilizing a light metal as discussed under the section dealing with the missile's central section.
82. The second warhead design engaged the efforts primarily of the ballistics and the aerodynamics section from November 1949 to February 1950. The basic idea behind the design was to utilize the tremendous kinetic energy of the warhead at propellant cut-off. At a speed of 4500 meters per second at cut-off, the kinetic energy when converted to heat energy would represent the energy equivalent to that of a high explosive. If a greater part of that speed could be maintained to the time of explosion, the total energy released, providing the explosion occurred above ground, would far exceed that of the explosive itself. The problem was to design a body with little resistance and still capable of withstanding the strain of the high speed flight. Since the ideal aerodynamic form could not be realized, it was decided that a return to the conic shape would have to be made and the added resistance accepted. The base of the cone was to be 1.4 meters in diameter and the length approximately six meters. Stability was to be maintained by filling the cone only partially with explosive. Two designs were accomplished. One was to utilize a thick steel wall. The other was to utilize a steel shell covered by a protective material. Apparently the design set up the specifications for materials to be used that had not been developed.
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84. At the completion of these supplementary designs, the Soviets took no action which would reflect their interest in the over-all R-14 project. Even the usual premiums, indicating satisfaction, were not paid to the Germans. Yet, no criticism was ever received. No indications were observed either as to the disposition of the project and further follow-up work or consultation was never requested.

85. [redacted] the Soviets anticipated the early repatriation of the Germans and [redacted] the project was an attempt to extract a few more ideas from the Germans prior to their leaving the USSR:

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Sketch page 23: Layout of the R-14 Missile
 Sketch page 25: Cross Sectional View of the Nose Section
 Sketch page 27: Cross Sectional View of the Warhead
 Sketch page 29: R-14 Central Section and Stabilizing Ring
 Sketch page 30: Details of Central Section and Stabilizing Ring
 Sketch page 32: Schematic Diagram of the R-14 Propulsion Unit and Propellant System

Sketch page 34: Layout of Rocket Motor for the R-14 Missile

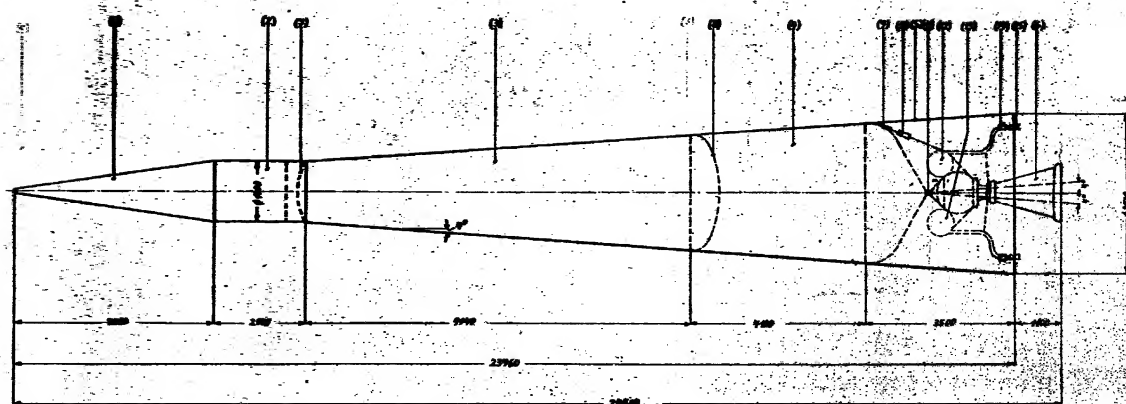
Sketch page 35: Details of Rocket Motor

Sketch page 37: Graphical Presentation of R-14 Motor Characteristics

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Note: All dims given in millimeters

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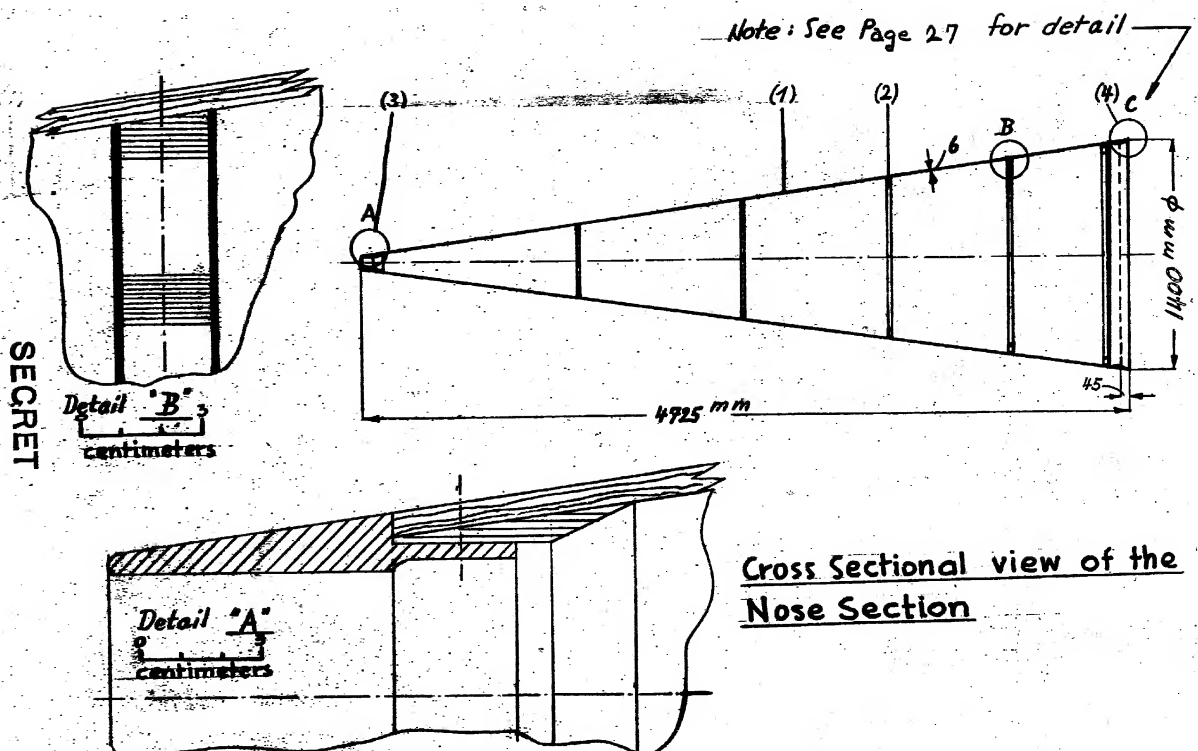
CROSS SECTION OF THE R-14 MISSILE

LEGEND

Scale: 1;50

1. Nose
2. Warhead
3. A-Propellant Container (A - Oxygen)
4. B-Propellant Container (B - Alcohol)
5. Stabilizing Ring
6. High Pressure Motor
7. Forward Container Panel
8. Partition
9. Aft Container Panel
10. Mechanism for Control of Rocket Motor Movement
11. Gimbal Mount
12. Turbine-Pump Unit
13. Turbine-Pump Unit
14. Mechanism for Controlling Turbine Exhaust Nozzle
15. Deflecting Turbine Exhaust Nozzle

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NOSE OF R-14 (Cross Section)

LEGEND

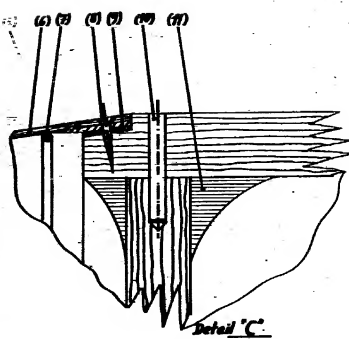
Scale: 1:25

1. Plywood Skin
2. Laminated Wood Former
3. Nose Opening
4. Re-inforced Joint (See sketch on p.27 for detail)

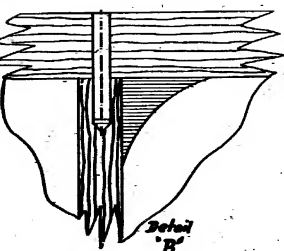
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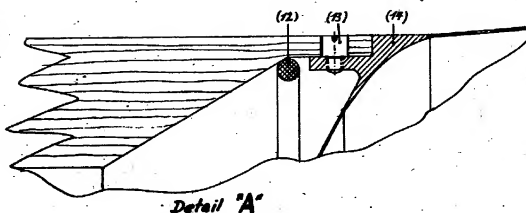
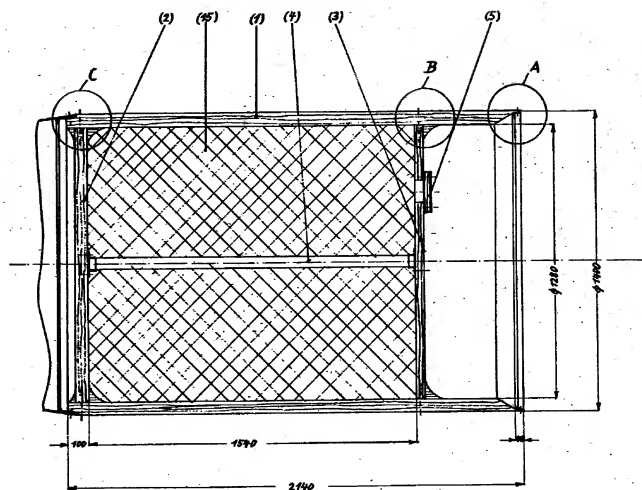
Cross Sectional View of the Warhead



Detail "C"



Detail "B"



Detail "A"

Note: All dims given in millimeters

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WARHEAD OF R-14

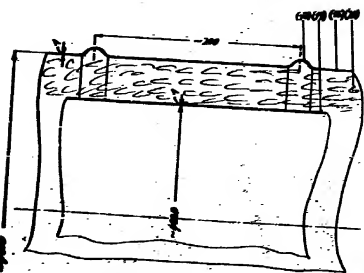
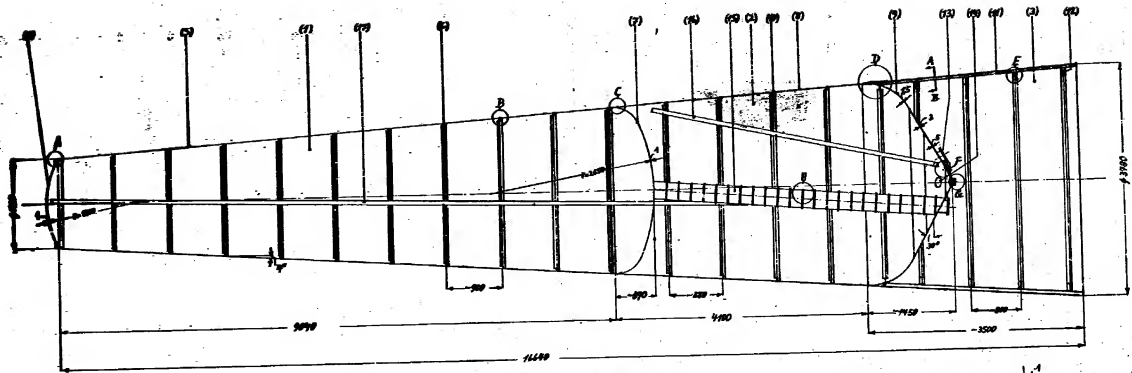
LEGEND

1. Plywood Case
2. Forward Plywood Panel
3. Aft Plywood Panel
4. Pipe Containing Initiating Explosives
5. Explosive Filling Opening
6. Plywood Nose Casing
7. Blasting Charge for 6
8. Screwed Connection to the Nose
9. Seal
10. Cemented Wooden Safety Pegs
11. Cemented Reinforcement Ring
12. Blasting Charge for the Separation of the Warhead from the Missile
13. Screwed Connection between the Warhead and the Missile
14. Connection Ring of the Central Section
15. Explosive

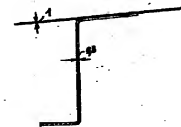
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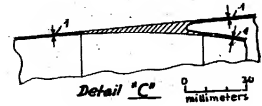
Note: Legend shown on page 31



Detail "H"
0 20 40
millimeters



Detail "B"
0 50 100
millimeters



Detail "C"
0 20 30
millimeters



Detail "F"
0 25 50
millimeters

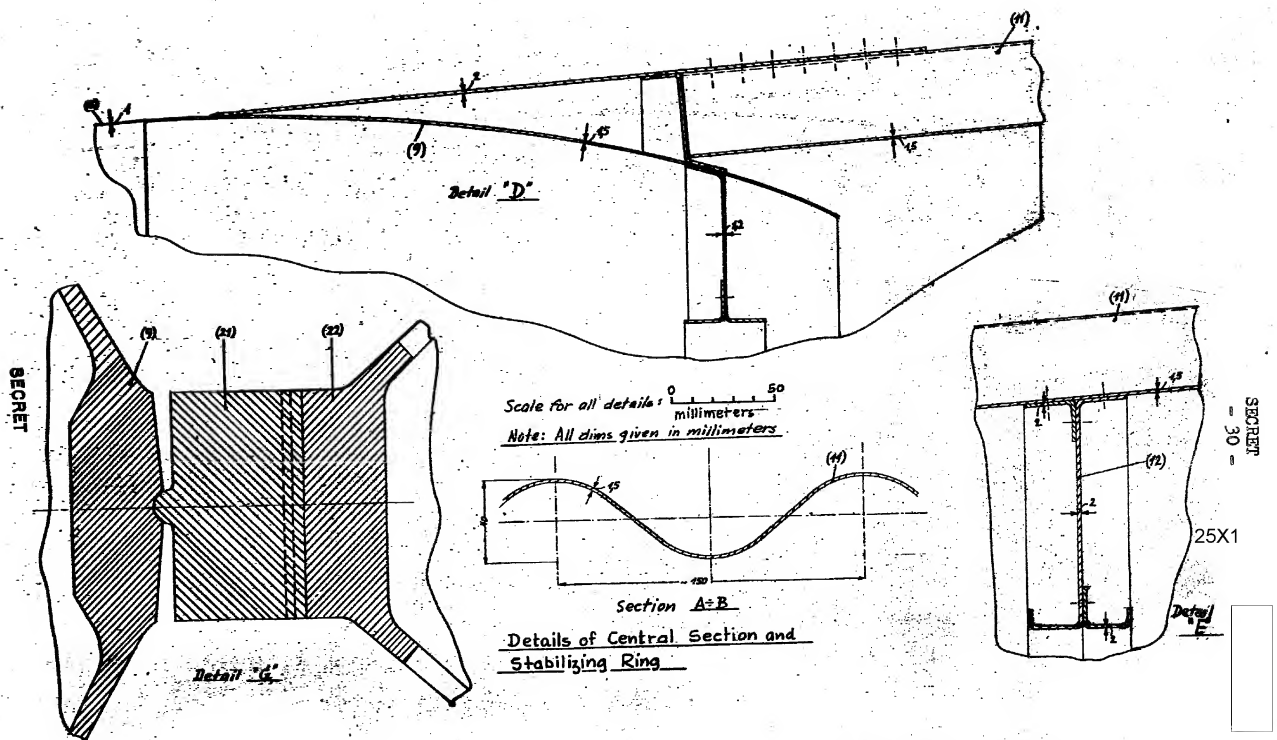
R-14 Central Section and Stabilizing Ring

Note: For detail "A" see page 28.
For details "D", "E", "G" and Section
1-3 see page 30

Note: All dims. given in millimeters

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CENTRAL SECTION AND STABILIZER RING OF R-14

1. "A" Container
2. "B" Container
3. Stabilizing Ring
4. Forward Panel (Special Steel)*
5. "A" Container Skin (Special Steel)*
6. "A" Container Former (Steel: σ_B = approx. 45 kg/mm²)
7. Container Partition (Special Steel)*
8. "B" Container Skin (Special Steel)*
9. Rear Panel (Special Steel)*
10. "B" Container Former (Steel: σ_B = approx. 45 kg/mm²)
11. Corrugated Casing ("Dural" σ_B = approx. 40 kg/mm²)
12. Stabilizing Ring Former ("Dural": σ_B = approx. 40 kg/mm²)
13. Alcohol Outlet
14. Alcohol Outlet for Lower Cooling Section
15. Reinforced Oxygen Outlet Casing (Steel: σ_B = approx. 60 kg/mm²)
16. "B" Container Vent Pipe (Steel)
17. "A" Container Vent Pipe (Steel)
18. Stiffening and Expansion Bead
19. Oxygen Outlet Pipe (Steel: σ_B = approx. 60 kg/mm²)
20. Glasswool Insulation
21. Ball Plate
22. Conic Shaped Motor Mount (Special Steel)*

*In a welded condition:

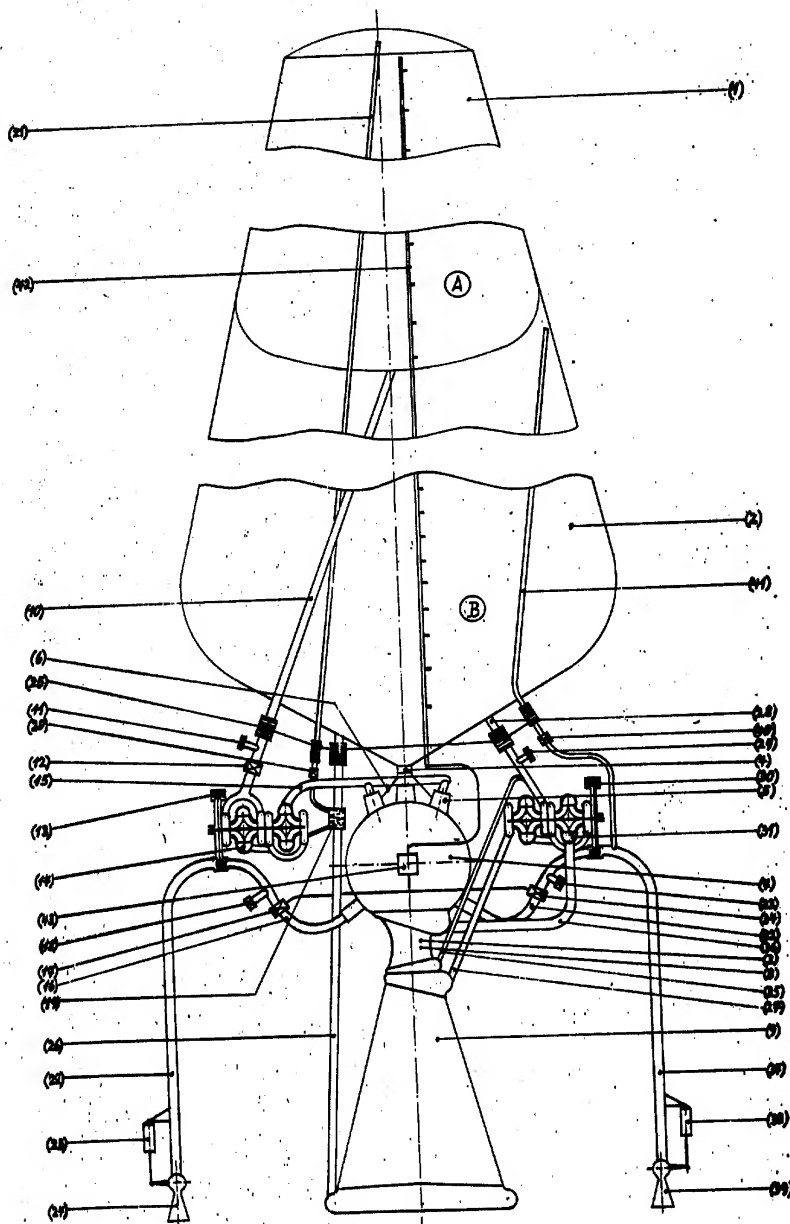
Elastic Limit σ_e 70 kg/mm²Tensile Strength σ_s 100 kg/mm²

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Schematic Diagram of the R-14 Propulsion Unit and Propellant System

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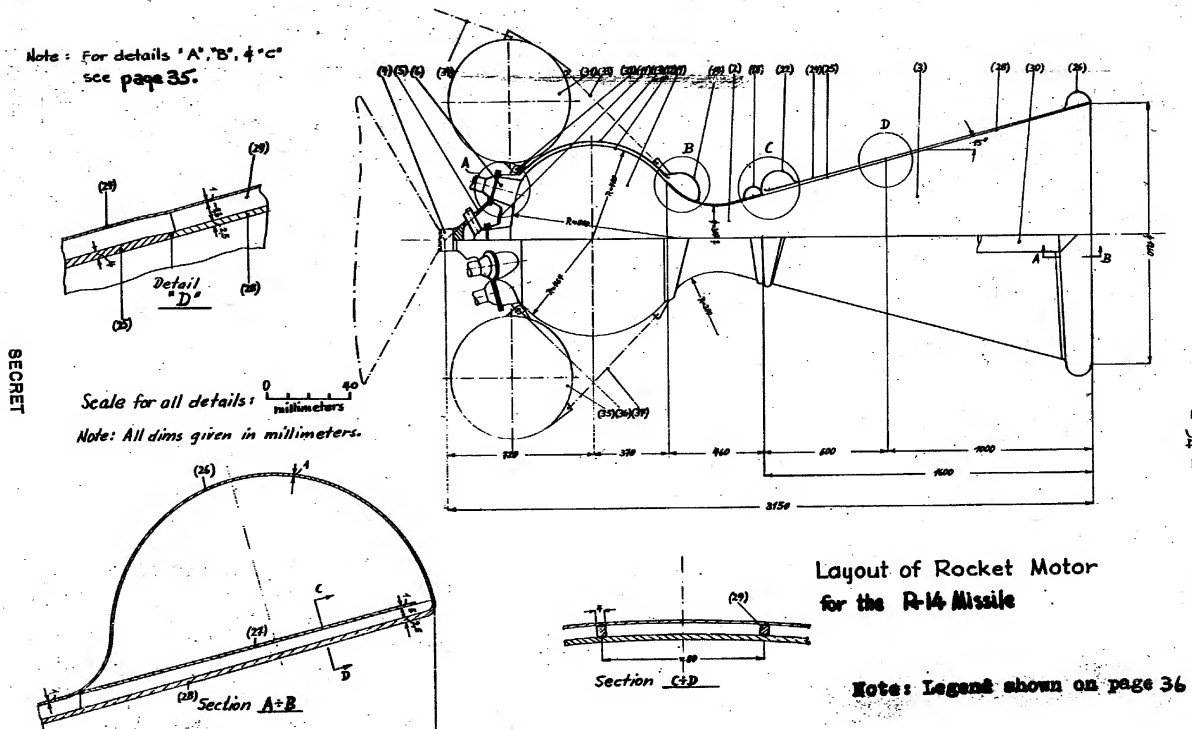
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SCHEMATIC DIAGRAM OF PROPULSION UNIT AND PROPELLANT SYSTEMLEGEND

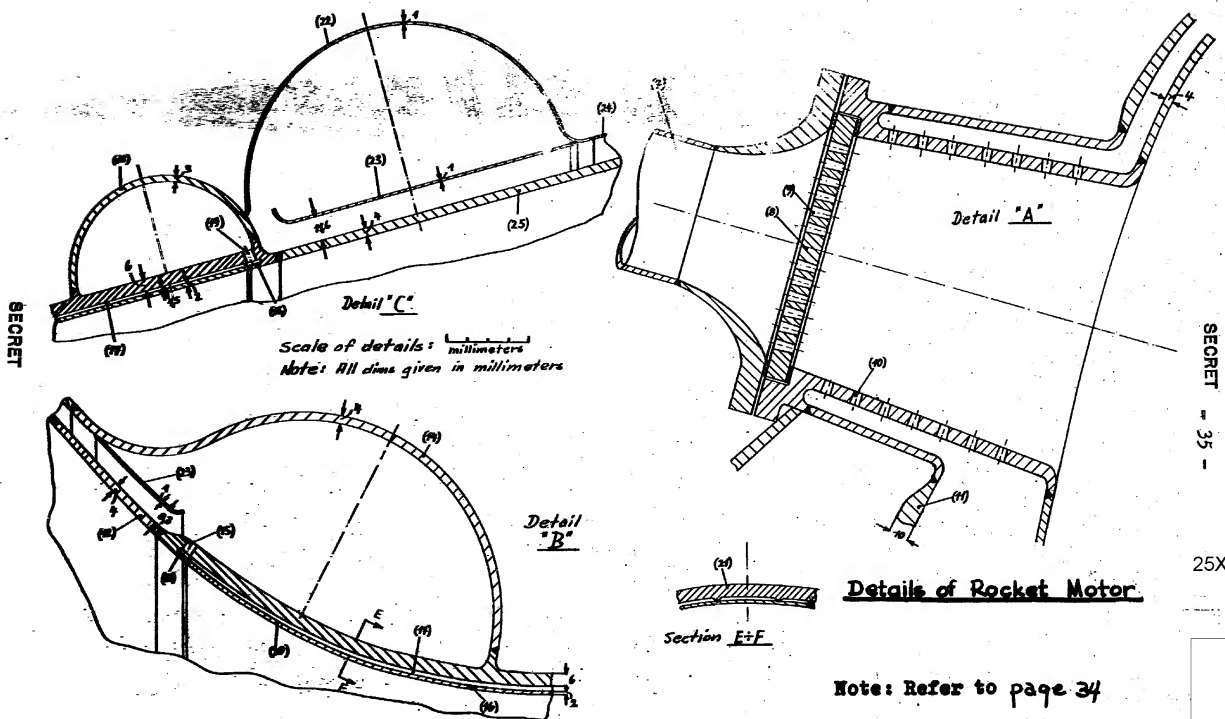
- | | |
|---|--------------------------------|
| 1. "A" Container | 34. Gas Control Valve |
| 2. "B" Container | 35. Alcohol Feed Pipe |
| 3. High Pressure Motor | 36. Alcohol High Pressure Line |
| 4. Gimbal Motor Mount | 37. Turbine Exhaust Pipe |
| 5. Injection Cup | 38. Control Motor |
| 6. Conic-shaped Motor Mount | 39. Turbine Exhaust Nozzle |
| 7. Chamber Cooling Section | 40. Reducing Control Valve |
| 8. Throat Cooling Section | 41. B Container Gasing Pipe |
| 9. Nozzle Cooling Section | 42. Propellant Measuring Unit |
| 10. A Feed Pipe | 43. Command Unit |
| 11. A Tank Filling Valve | |
| 12. A Cut-Off Valve | |
| 13. 2 Stage Turbine | |
| 14. 2 Stage A-Pump | |
| 15. High Pressure A-Line | |
| 16. Gas Extraction Pipe | |
| 17. Control Valve | |
| 18. Compressed Air Starting Valve | |
| 19. A Vaporizer | |
| 20. A Reducing and Control Valve | |
| 21. A Gasing Pipe | |
| 22. Turbine Exhaust Pipe | |
| 23. Control Motor | |
| 24. Turbine Exhaust Nozzle | |
| 25. Flexible Pipe Unions | |
| 26. "B" Feed Line to Nozzle Cooling Section | |
| 27. "B" Cooling Line | |
| 28. "B" Feed Line | |
| 29. "B" Container Filling Valve | |
| 30. 2 Stage Turbine | |
| 31. 2 Stage Pump (B) | |
| 32. Gas Extraction Pipe | |
| 33. Compressed Air Starting Valve | |

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DESIGN OF THE HIGH PRESSURE MOTOR (R-14)

1. Combustion Chamber
2. Throat
3. Nozzle
4. Gimbal Plate (Hardened Steel)
5. Conic Motor Mount (Special Steel)*
6. Injection Cups
7. "A" Material High Pressure Line ($\sigma_B = \text{approx. } 24 \text{ kg/mm}^2$)
8. "A" Material Injection Plate
9. "A" Material Injection Orifices
10. "B" Material Injection Orifices
11. Outer Casing of Combustion Chamber Head (Special Steel)*
12. Combustion Chamber Inner Wall (Special Steel)*
13. Combustion Chamber Casing (Special Steel)*
14. Cooling Inlet Ring (Special Steel)*
15. Throat Coolant Orifices
16. Coolant Injection Orifices
17. Throat Coolant Slot
18. Throat Coolant Outlet Ring (Special Steel)*
19. Coolant Orifice
20. Throat Wall
21. Throat Casing
22. Nozzle Coolant Outlet Ring
23. Coolant Baffle
24. Nozzle Casing (Special Steel)*
25. Nozzle Wall
26. Nozzle Coolant Inlet Ring (Special Steel)*
27. Coolant Baffle
28. Nozzle Wall (Special Steel)*
29. Longitudinal Ribs
30. Feed Line
31. "B" Material Turbine-Pump Assembly
32. Turbine Pump Assembly Attachment (2 points)
33. Support Struts for 31
34. Push Rod for Motor Deflection
35. "A" Material Turbine-Pump Assembly
36. Turbine-Pump Assembly Attachment (2 points)
37. Support Struts

*In welded condition:

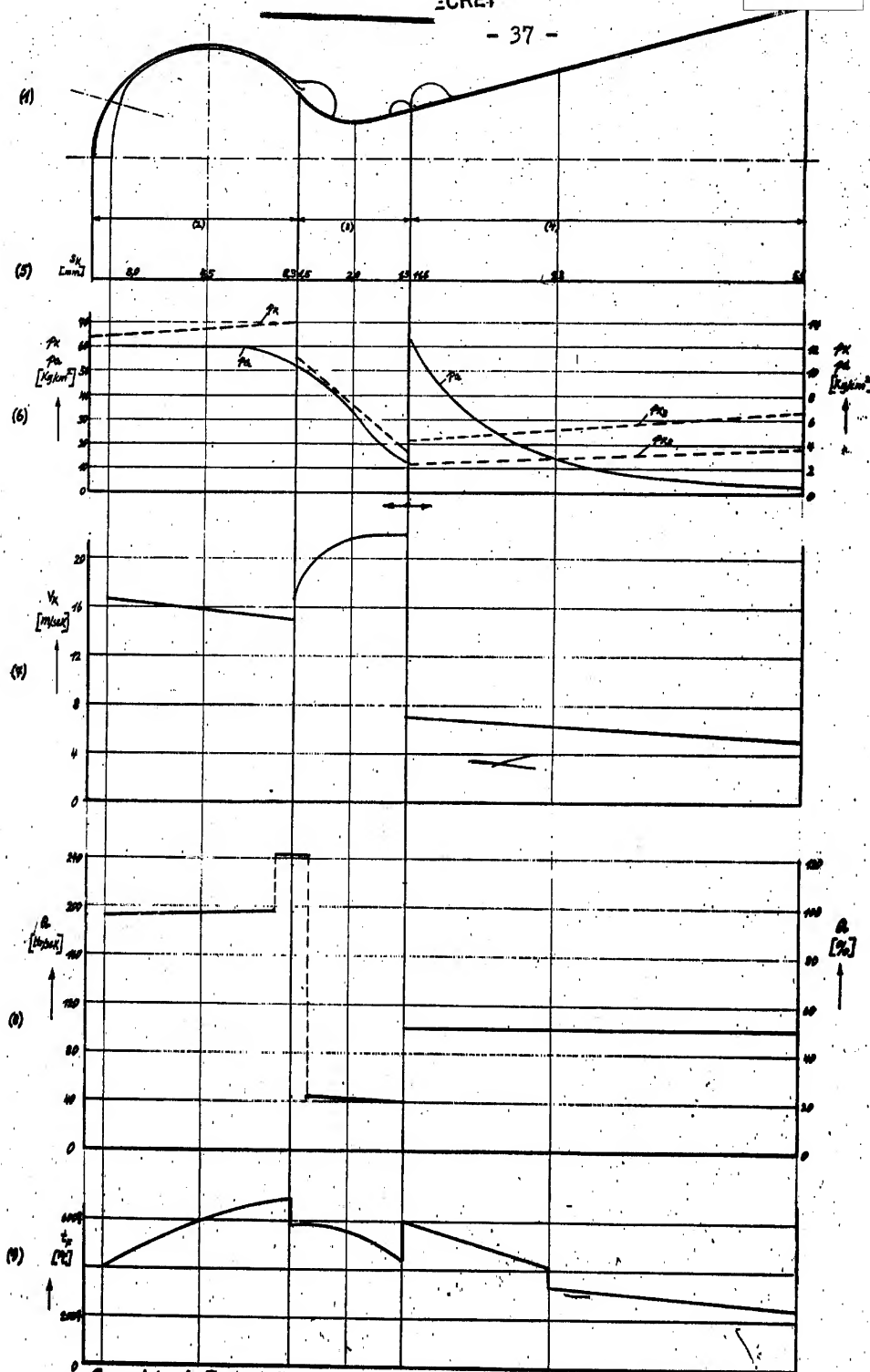
Elastic Limit σ_e 70 kg/mm²Tensile Strength σ 100 kg/mm²

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Graphical Presentation of R-14 Motor Characteristics

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